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**TITLE:** THE HIGHEST TEMPERATURES RECORDED BY THE OKLO MINERAL PHASE ASSEMBLAGES AND ROCK TEXTURES

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THE HIGHEST TEMPERATURES RECORDED BY THE OKLO MINERAL  
PHASE ASSEMBLAGES AND ROCK TEXTURES

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ABSTRACT

Biotite-bearing pelitic phase assemblages are observed in reactor zones 2 and 5 and up to at least 4 m. outside of zone 2, indicating a minimum temperature in these regions of about 400°C. Rock textures suggest that still higher temperatures may have been reached within the reactors.

## THE HIGHEST TEMPERATURES RECORDED BY THE OKLO MINERAL PHASE ASSEMBLAGES AND ROCK TEXTURES

The mineral phase assemblage observed in a rock is a function of its bulk chemistry and of its environment through time, specifically its history of temperature, pressure, and imposed chemical potentials. Pelitic compositions such as those found in the phyllitic groundmass of nearly all of the Oklo rock types can be particularly useful as temperature indicators and moderately useful for pressure. Both temperature and pressure, however, may have reached maxima and subsequently dropped, tending to produce a sequence of retrograde mineral phases. The problem then becomes one of searching for any surviving islands of higher grade mineral assemblages. Such higher grade assemblages will indicate minimum conditions that that part of the rock must have reached at some time in the past.

Four sample traverses that go to or into the reactor zones have been studied and are listed in Table 1. There are two additional samples near zone 5 and two inside zone 2.

New biotite-bearing pelitic phase assemblages are commonly observed close to and inside of the reactor zones. Table 2 gives typical electron microprobe analyses of the coarser biotite grains. Significant amounts of  $K_2O$ ,  $MgO$ , and  $FeO$  have been lost from the biotite mineral matrices leaving skeletons rich in  $SiO_2$  and  $Al_2O_3$ . Muscovite and chlorite are similarly depleted. Figure 1A shows a residual region of muscovite-biotite schist in sample #2184. This small island is surrounded by shear zones composed primarily of muscovite and chlorite.

Figure 1B shows typical pseudomorphs of fibrolitic sillimanite observed in sample #2282. Their present chemical composition is that of chlorite (e.g., large mass at lower right) or kaolin (smaller mass in upper left). Sample #2282 includes both probable detrital material and angular breccia fragments. The metamorphic grade of the fragments ranges from low temperature greenschist facies phyllites to altered high temperature amphibolite facies schists. The most recent faulting thus postdated a metamorphic event. The sillimanite may have been introduced in detritus or breccia or it may have formed nearby and later retrograded. The  $Al_2O_3$ - $SiO_2$  composition of sillimanite may have helped preserve its texture.

Temperatures above  $400^\circ C$  are indicated by the biotite-bearing pelitic assemblages that are observed in reactor zone 5 and that begin as much as 4 m. outside of reactor zone 2 ([1] Winkler, 1974). Detrital mica disappears approximately concurrently with the appearance of biotite. No garnet or good chlorite pseudomorphs of garnet are observed. The absence of garnet suggests pressures below 4 kilobars. Fibrolitic sillimanite formation would require temperatures of at least  $600^\circ C$  under relatively shallow (less than 7 km.) conditions.

The fact that temperatures of at least  $400^\circ C$  were encountered several meters outside of reactor zone 2 suggests that higher temperatures may have been reached in the reactor's interior. Relict textures in the reactor zone rock also suggest temperatures near or a little above the minimum melting

point (650-700°C). Strong chemical zonation characteristic of high temperatures is observed in both zones 5 and 6, e.g. regions of fine-grained muscovite rimmed by biotite or chlorite and the reverse. Figure 2 shows curious globular features in zone 2 that resemble immiscible viscous felsic melt in a more fluid mafic melt. Other reactor zone textures (e.g. samples #2374 and #1183) suggest possible plastic flow. Temperatures above 600°C may have been reached within the reactors.

#### REFERENCE

- [1] WINKLER, H. G. F., 1974, Petrogenesis of metamorphic rocks: Springer-Verlag, New York.

TABLE 1

Traverse	Sample Location	COMUF #	Rock Type *	Highest Temperature Mineral in New Pelitic Phase Assemblage
Across zone 5	1 m. below lower edge	2181	gres fin	chlorite**
	.25 m. " " "	2183	argile verte	chlorite
	.75 m. above " "	2184	facies-pile	biotite
	near reactor center	2186	" "	biotite
	.75 m below upper edge	2190	" "	chlorite
	.5 m above " "	2192	conglomerat	chlorite
	1.5 m. " " "	2194	gres argileux	chlorite**
	2.0 m. " " "	2195	gres moyen	chlorite**
Near zone 5	3 m. outside	2200	moyen congl.	chlorite
	1.5 m. outside	2161	gres moyen	chlorite
Northwest Edge of zone 2	1 m. outside	2430	sandstone	chlorite
	.5 m. outside	2429	sandstone	chlorite
	.5 m. outside	2428	sandstone	chlorite
	2 m. inside	1899/5	facies-pile	minor biotite
	2 m. inside	1421/5	facies-pile	minor biotite
Southeast Edge of zone 2	4 m. outside	1022	sandstone	minor biotite
	3 m. outside	1021	fault breccia	minor biotite
	2 m. outside	1017	" "	biotite
	1 m. outside	1013	" "	biotite
	reactor edge	1009	extreme "	chlorite
Southwest Edge	3.5 m. outside	2292	fault breccia	chlorite
	2.5 m. outside	2283	" "	chlorite
	2 m. outside	2282	" "	minor biotite
	.5 m. inside	1755	facies-pile	chlorite
Inside zone 2		2374	facies-pile	biotite
		1183	" "	biotite

\* French name assignments used where known, otherwise, name derived from texture in thin section.

\*\* A pleochroic brown Fe-rich muscovite is also present.

TABLE 2

## TYPICAL BIOTITE ELECTRON MICROPROBE ANALYSES IN WEIGHT PERCENT

<u>Sample #</u>	<u>2184</u>	<u>2184</u>	<u>2190</u>	<u>1899/5</u>	<u>1421/5</u>	<u>1421/5</u>	<u>2374</u>	<u>2374</u>	<u>1183</u>	<u>1183</u>
SiO <sub>2</sub>	38.46	38.55	37.54	37.19	37.98	37.73	37.10	35.57	37.26	38.73
TiO <sub>2</sub>	0.07	0.08	0.06	0.07	0.11	0.65	0.07	0.04	0.05	0.04
Al <sub>2</sub> O <sub>3</sub>	23.54	21.87	28.44	24.70	25.71	25.08	21.16	22.70	24.30	24.85
FeO	14.23	20.98	11.64	10.39	10.74	10.58	19.80	16.06	20.26	16.31
MnO	0.05	0.08	0.07				0.50	0.52	0.19	0.13
MgO	1.09	0.85	1.35	12.89	12.42	13.16	4.21	6.72	6.47	6.25
CaO	0.16	0.30	0.22	0.15	0.30	0.25	0.10	0.16	0.28	0.21
Na <sub>2</sub> O	0.06	0.07	0.06	0.10	0.09	0.07	0.11	0.08	0.04	0.07
K <sub>2</sub> O	4.63	2.42	1.12	0.47	0.49	0.52	3.10	1.34	1.75	1.45
F	0.28	0.00	0.39				0.30	0.00	0.26	0.53
Cr <sub>2</sub> O <sub>3</sub>	0.02	0.07	0.03				0.02	0.00	0.01	0.04
Total	82.59	85.27	80.92	85.96	87.84	88.04	86.47	83.19	90.87	88.61

## FIGURE CAPTIONS

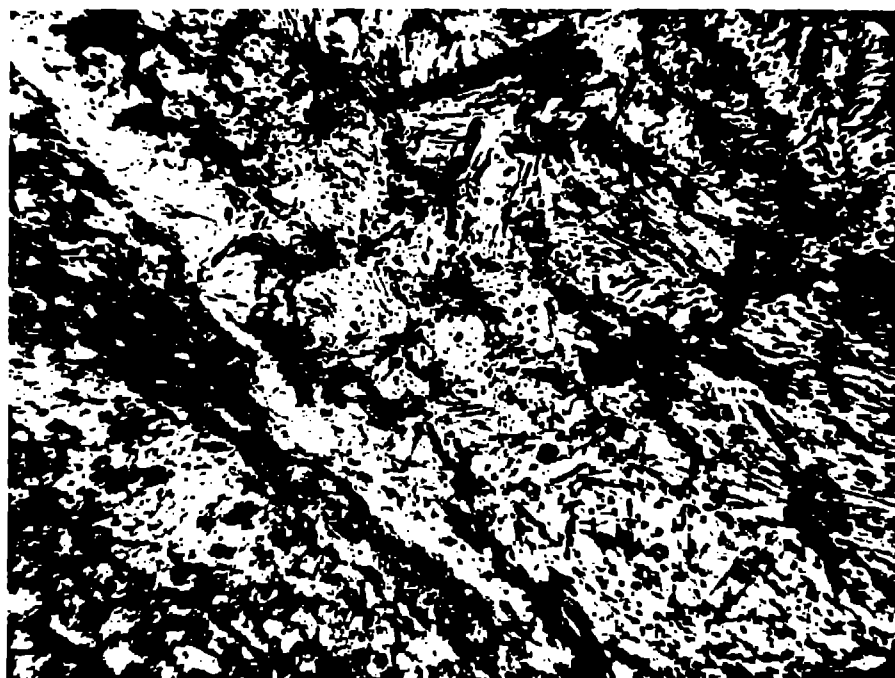
### Figure 1

- A) Muscovite (white in photo) and biotite (light grey) schist region bordered by lower grade fine-grained assemblages at lower left (sample #2184, 220X)
- B) Pseudomorphs after fibrolitic sillimanite in lower right and upper left of photo (sample #2282, 220X)

### Figure 2

- A) Curious blobby textures in reactor zone 2 sample (#1421/5, 88X)
- B) Higher magnification of right central region above (#1421/5, 220X)

A



B

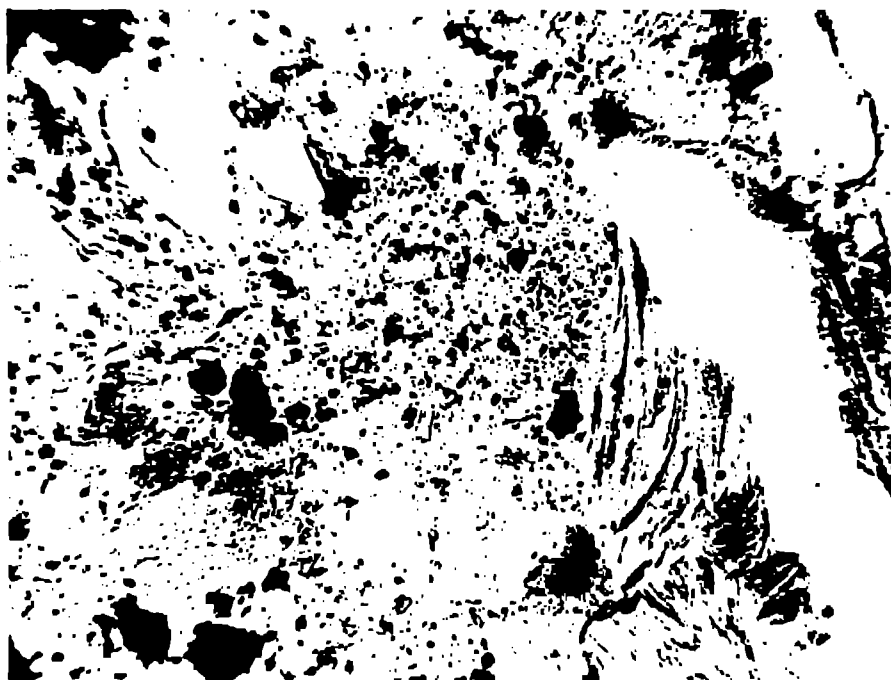
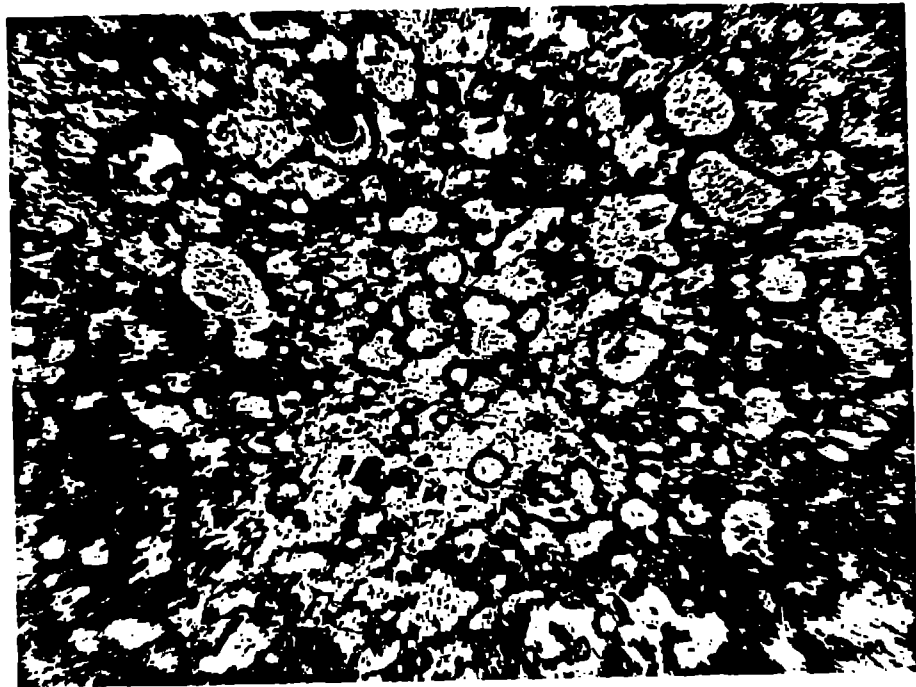


FIGURE 1

A



B

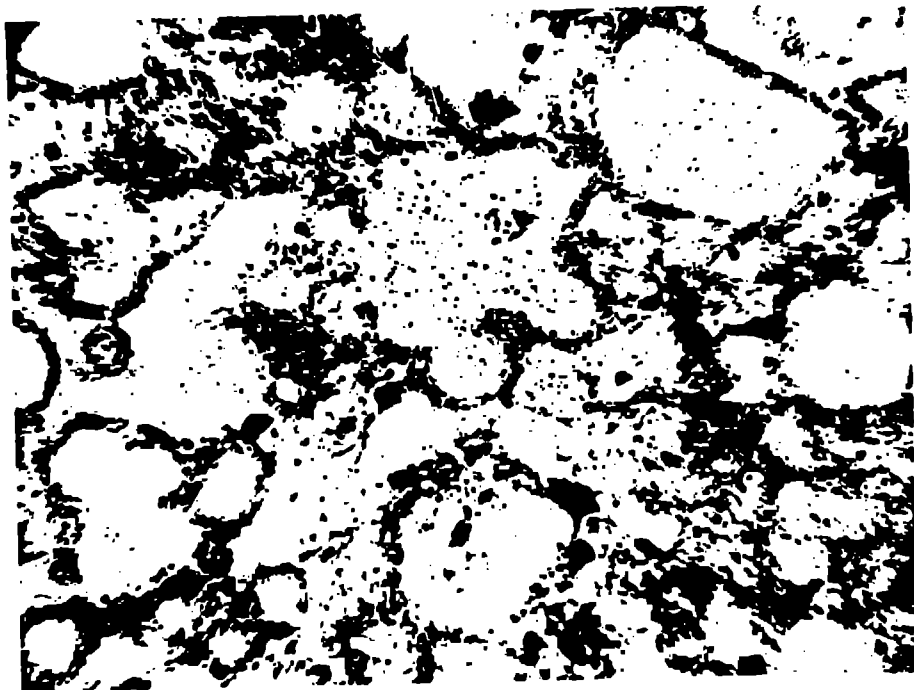


FIGURE 2